MINISTRY OF HEALTH OF UKRAINE
Zaporizhzhia State Medical University
Analytical Chemistry Department

# MEDICAL CHEMISTRY
## Module 1

# THERMODYNAMIC AND KINETIC REGULARITY OF THE REACTION BEHAVIOR AND ELECTROKINETIC PHENOMENA IN BIOLOGICAL SYSTEMS

(Abstract)

## Topic module 3

Manual
for teachers and students
of the 1-st course of the Medical Faculty
speciality«General Medicine»

Zaporizhzhia
2013

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**Module 1. Medical chemistry.** Topic module 3. Thermodynamic and kinetic regularity of the reaction behavior and electrokinetic phenomena in biological systems (abstract) : manual for teachers and students of the 1-st course of the Medical Faculty speciality "General Medicine" / comp. S. A. Vasyuk, A. S. Korzhova, U. M. Zhuk. – Zaporizhzhia : [ZSMU], 2013. – 76 p.

*The Manual is considered and approved at the meeting of The Central Methodical Council of Zaporizhzhia State MedicalUniversity (record № 3 of 22.02.2013)*

# PREFACE

Medicalchemistryisstudiedaccordingtotheapprovedstandardofacademiccurriculumof 2005 yearfor students of the Universities of the III-IV levels of accreditationof Ukraine forspecialty 7.110101 "Generalmedicine" fieldofstudy 1101 "Medicine" isestablishedinaccordancewiththeeducationalandskillcharacteristics (ESC) andeducationandprofessionalprograms (EPP) trainingapprovedbyorderoftheMinistryofEducationofUkrainefrom 16.04.03 № 239.

Organization of studying process is proceed according to the requirements ofEuropeanCreditTransferSystem (ECTS).

StudyofMedicalChemistryiscarriedoutduring 1 semesterof 1st yearoftraining according to theacademic curriculum.

Thecurriculumconsistsof a disciplinemodule, including 4 blocksoftopicmodules:

1. Chemistryofbiogenicelements. Complexformationinbiologicalfluids.
2. Acid – baseequilibriumsinbiologicalfluids.
3. Thermodynamic andkineticprocessesregularitiesandelectrokineticphenomenainbiologicalsystems.
4. Physicsandchemistryofsurfaceeffects. Lyophobicandlyophilicdispersesystems.

# TOPIC MODULE 3

# THERMODYNAMIC AND KINETIC REGULERITY OF REACTION BEHAVIOR AND ELECTROKINETIC PHENOMENA IN BIOLOGICAL SYSTEMS

# Tutorial № 11

**1. THEME: Thethermaleffectsof a chemicalreaction. Processesdirection**

**2. PURPOSE: To study the laws of chemical thermodynamics, as the theoretical base of bioenergy. Be able to interpret the basic laws of thermodynamics for describing biological processes**

3. OBJECTIVIES:

3.1. To learn the basic concepts of thermodynamics.

3.2. To learn the basic laws of thermodynamics.

3.3. To learn to conduct thermochemical calculations and to use them for determination of the reaction enthalpy.

4. PLAN AND ORGANIZATIONAL STRUCTURE OF THE TUTORIAL:

4.1. Organizational part……………………………………………………5 min
4.2. Goal-setting and motivation of the theme studying (opening address of the teacher)………………………… ………………………………………5 min
4.3. Determination of initial knowledge level………………………………15 min
4.4. Correction of the initial knowledge level……….………………………25 min
4.5. Organization of independent work of students (target teacher guidance, rules of accident prevention)……… ………………………………………………5 min
4.6. Laboratory work……………………………………….…………………45 min
4.7. Final control: checking of the laboratory work results and protocols………………………………………………………..........................10 min
4.8. Concluding remarks of the teacher, instructional lines for the next lesson……………………………………………………….........................3 min

## 5. REFERENCE FOR SELF-STUDY:

### 5.1. Questions for self-study

1. The subject of chemical thermodynamics. Basic concepts of chemical thermodynamics: thermodynamic system (isolated, closed, open, homogeneous, heterogeneous), the parameters of state (extensive, intensive), thermodynamic process (reversible and irreversible).
2. Living bodies are open thermodynamic systems. Irreversibility of the vital processes.
3. The first law of thermodynamics.
4. Enthalpy.
5. Thermochemical equations. Standard enthalpies of formation and combustion.
6. Hess's law. The colorimetric detection method. Energy characteristic of biochemical processes. Thermochemical calculations for evaluation of food energy value and composition of balanced medical diets.
7. Spontaneous and non-spontaneous processes. The second law of thermodynamics.
8. Entropy.
9. Thermodynamic potentials: Gibbs energy, Helmholtz energy. Thermodynamic equilibrium conditions. Directionality criteria of spontaneous processes.
10. Application of basic concepts of thermodynamics to living bodies. ATP as the energy source of biochemical reaction. Macroergic compounds. Energy coupling in living systems: ekzergonic and endergonic processes in the body.

### 5.2. Solve the tasks:

**Task 1.**Calculate the enthalpy of the reaction

$CO_{(g)} + 3H_{2(g)} = CH_{4(g)} + H_2O_{(g)}$, if enthalpies of formation are equal to: $CO_{(g)}$ = –110 kJ/mole, $CH_{4(g)}$= –74,9 kJ/mole, $H_2O_{(g)}$ = –241,8 kJ/mole.

Answer: – 206,2 kJ/mole.

**Task 2.**Calculate the enthalpy of the reaction of glucose alcoholic fermentation $C_6H_{12}O_{6(f.)} = 2CO_{2(f.)} + 2C_2H_5OH_{(f.)}$, if the combustion enthalpies of glucose is –2815,8 and of ethanol is –1366,9 kJ/mole.

Answer: – 82,0 kJ/mole.

**Task 3.**Whether reaction occurs spontaneously:
$SiO_{2(c)} + NaOH_{(f.)} = Na_2SiO_{3(c)} + H_2O_{(f.)}$, if Gibbs energy is equal to:$SiO_{2(c)}$ = –803,75 kJ/mole; $NaOH_{(f.)}$= –419,5 kJ/mole; $Na_2SiO_{3(c)}$ = –1427,8 kJ/mole; $H_2O_{(f.)}$ = –237,5 kJ/mole?

Answer: yes.

## 5.3. Examples of the solved tasks:

**Task 1.** Calculate the enthalpy of hydration $CaCl_2$, knowing that the dissolution of 1 mole of anhydrous $CaCl_2$ - 72.7 kJ of heat is released, and the dissolution of 1 mole of crystallohydrate $CaCl_2 \cdot 6H_2O$ - 18.0 kJ of heat is absorbed.

***Solution.*** The dissolving process of calcium chloride in water can be divided into two stages:

The first stage – the hydration process that is, obtaining of crystallohydrate, the heat of which is necessary to calculate:

$$CaCl_{2(c)} + 6H_2O_{(f)} = CaCl_2 \cdot 6H_2O_{(c)} \quad (\Delta H_1),$$

The second stage - crystallohydrate dissolution in water:

$$CaCl_2 \cdot 6H_2O_{(c)} + aq = CaCl_2\,aq_{(f)} + 6H_2O_{(f)}\ \ (\Delta H_2)$$

Total heat effect $\Delta H_1 + \Delta H_2$is the heat of dissolution of anhydrous salt $\Delta H_3$:

$$CaCl_{2(c)} + aq = CaCl_2\,aq_{(f)}\ \ (\Delta H_3)$$

The difference between the enthalpies of anhydrous salt dissolution ($\Delta H_3$) and crystallohydrate dissolution ($\Delta H_2$) is the enthalpy of hydration ($\Delta H_1$).

Substituting the appropriate values of the thermal effects, we obtain:

$$\Delta H_{hydr.} = -72{,}7 - 18{,}0 = -90{,}7 \text{ kJ},$$

so, in the hydration process of 1 mole of $CaCl_2$ 90,7 kJ of heat are released.

**Task 2.**Whether the spontaneous reaction of glucose oxidation at 25 ° C possible:

$C_6H_{12}O_{6(f)} + 6O_{2(g)} \rightarrow 6CO_{2(g)} + 6H_2O_{(f)}$

***Solution.***Calculate the Gibbs energy change for this reaction, using the table data of standard enthalpies and entropies by formula:

$$\Delta G = \Delta H - T\Delta S$$

T = 273 + 25 = 298 K

$\Delta G = (6 \cdot \Delta H^{\circ} CO_{2(g)} + 6 \cdot \Delta H^{\circ} H_2O_{(f)} - \Delta H^{\circ} C_6H_{12}O_{6(f)}) - 298 \cdot (6 \cdot \Delta S^{\circ} CO_{2(g)} + 6 \cdot \Delta S^{\circ} H_2O_{(fl)} - \Delta S^{\circ} C_6H_{12}O_{6(f)} - 6 \cdot \Delta S^{\circ} O_{2(g)}):1000 = = (6 \cdot (-393{,}5) + 6 \cdot (-285{,}8) - (-1274{,}4)) - 298 \cdot (6 \cdot 213{,}64 + 6 \cdot 69{,}94 - 212{,}13 - 6 \cdot 205{,}0):1000 = -2879$ kJ/mol

Thus, the glucose oxidation is a spontaneous process, since the Gibbs energy change is negative ($\Delta G < 0$).

## 5.4. Study tests (p. 55).

## Literature:

1. Medical Chemistry : textbook / V. A. Kalibabchuk [and ol.] ; ed. by V. A. Kalibabchuk. - K. : Medicine, 2010. - p.24-36
2. LevitinYe.Ya. General and Inorganic Chemistry : textbook for students of higher schools / Ye. Ya.Levitin, I. A. Vedernikova. - Kharkiv : Golden Pages, 2009. - 360 p.
3. Inorganic Chemistry : textbook / ed.: D. F. Shriver, P. W. Atkins. - 3th ed. - [s. l.] : Oxford University Press, 2004. - 763 p.

## 6. LABORATORY WORK

### 6.1. Evaluation of enthalpy hydration

Evaluation of enthalpy hydration of salt comes to evaluation of enthalpies of anhydrous salt solution of and its crystallohydrate. You need to take 8 gr of powdered crystallohydrate ($CuSO_4{\cdot}5H_2O$) and put it into Dewar's vessel, pour 77 ml of d-water, mix everything and measure the maximum temperature. Carry out the experiment with anhydrous salt $CuSO_4$ similarly (accurate weight of a/h $CuSO_4$ – 5 gr, d-water – 80ml). In the first experiment it was taken 3 gr of water less, which is equal to the water contained in 8 gr of crystallohydrate.

Evaluate enthalpy of solution of $CuSO_4{\cdot}5H_2O$ and $CuSO_4$:

$$\Delta H_{\text{hydr.}} = \frac{K \cdot (t_{\text{water}} - t_{\text{max solution}}) \cdot M}{m \cdot 1000}$$

m – weight of salt, g;

M – molar weight of salt, g/mole;

K – constant of the calorimeter, which is experimentally or calculated by the formula:

$$K = \sum m \cdot c \text{, where}$$

m–weigh of device parts and fluid;

c – specific heat capacity

($c_{glass}$ = 0,753 J/g·K; $c_{\text{water and diluted solutions}}$ = 4,184 J/g·K).

For date conditions in the work:

$K = m_{glass} \cdot c_{glass} + m_{sol.} \cdot c_{sol.} = 52 \cdot 0{,}753 + 85 \cdot 4{,}184 = 374{,}5$ J/g·K.

Enthalpy of hydration is evaluated by formula:

$$\Delta H_{hydr.} = \Delta H_{hydr.a/h\ salt} - \Delta H_{hydr.crystal.}$$

## 6.2. Evaluation of neutralization enthalpy

You need to measure the temperature of initial solutions, then pour 40 ml 2 N of NaOH solution into Dewar's vessel, then pour 40 ml 2 N of HC1 solution; quickly close the vessel with the cork with the thermometer and measure the maximum temperature. Carry out the experiments with other bases and acids similarly. Putdowntheresultsintothetable:

| № | Base | $V_{b.}$, ml | $t_{base}$ | Acid | $V_{acid}$, ml | $t_{acid}$ | $t_{mix.}$ |
|---|---|---|---|---|---|---|---|
| 1 | 2 n. NaOH | 40 | | 2 n. HCl | 40 | | |
| 2 | 2 n. NaOH | 40 | | 2 n. $H_2SO_4$ | 40 | | |
| 3 | 2 n. NaOH | 40 | | 2 n. $CH_3COOH$ | 40 | | |
| 4 | 2 n. $NH_4OH$ | 40 | | 2 n. $CH_3COOH$ | 40 | | |

Evaluate neutralization enthalpy by formula:

$$\Delta H_{neutr.} = \frac{\left(t_{mix.} - \frac{t_{base} + t_{acid}}{2}\right) \cdot К}{V \cdot C_{m.}} =$$

V =$V_{base.}$ = $V_{acid}$ – volume of solution, ml;

$C_{n.}$ – molar concentration of solution, mole/l;

К – coefficient, which is calculated by formula:

$$К = m_1 \cdot c_{1} + 2 \cdot V \cdot \rho \cdot c_2, \text{ where}$$

$m_1$ –weight of calorimeter glass;

$c_1$–specific heat capacity of glass (0,753 J/g·К);

ρ –density of solution;

$c_2$ –specific heat capacity of water and diluted solutions (4,184 J/g·К).

For date conditions in the work:

К = 374,5.

## 7. TRAINING AND TESTING MEANS

– table funds on the theme of the tutorial;

– card for determination of initial level of knowledge and skills;

–questions for review;

– tests.

## Tutorial № 12

**1. THEME: Kinetics of biochemical reactions**

**2. PUROSE: To study the laws and rules of the kinetics and be able to interpret them for the characterization of biological processes**

### 3. OBJECTIVIES:

3.1. To learn the basic concepts of chemical kinetics.

3.2. To learn the basic laws and rules of the kinetics.

3.3. To be able to explain the effects of various factors on the rate of chemical reactions.

3.4. To learn to define the order and molecularity of the reactions.

### 4. PLAN AND ORGANIZATIONAL STRUCTURE OF THE TUTORIAL:

4.1. Organizational part……………………………………………5 min

4.2. Goal-setting and motivation of the theme studying (opening address of the teacher)…………………………… ………5 min

4.3. Determination of initial knowledge level…………………15 min

4.4. Correction of the initial knowledge level………..……….25 min

4.5. Organization of independent work of students (target teacher guidance, rules of accident prevention)……… ……………….5 min

4.6. Laboratory work…………………………………….……….45 min

4.7. Final control: checking of the laboratory work results and protocols…………………………………………………....10 min

4.8. Concluding remarks of the teacher, instructional lines for the next lesson…………………………………………………......3 min

# 5. REFERENCE FOR SELF-STUDY:

## 5.1. Questions for self-study

1. Chemical kinetics,as a basisfor studying therateand mechanismof biochemical reactions.
2. The rate of the reactions. The dependence of thereaction rate on theconcentration.The lawof mass action.Constantof the reaction rate.Reaction order.The kineticequation for the reactionof the first,second andzeroth order.
3. The half-life is a quantitative characteristic of the changes in the concentrationof radionuclides, pesticides, etc. in the environment.
4. The concept of thereaction mechanism.Molecularityofthereactions.
5. The dependence of the reaction rate on temperature. The rule of van't Hoff. Features of the temperature coefficient of the reaction rate for biochemical processes.
6. The activation energy. Theory of active collisions. Arrhenius equation. The concept of the theory of the transition state (activated complex).
7. Concept of the kinetics of complex reactions: parallel, consecutive, coupled, chain. The concept of antioxidants. Free radical reactions in vivo. Photochemical reactions, the photosynthesis.
8. Catalysis and catalysts. Peculiarities of catalysts. Homogeneous, heterogeneous and microheterogeneous catalysis. Acid-base catalysis.Autocatalysis. Mechanism of catalysis effect. Promoters and catalytic poisons.
9. The concept of kinetics of enzymes reactions. Enzymes as biological catalysts. Peculiarities of enzymes effect: selectiveness, effectiveness, dependence of enzymes effect on temperature and environmental reaction. The concept of enzymes effect mechanism. Dependence of enzymes processes rate on enzymes

and substrate concentration. Activation and inhibition of enzymes. The effect of ecological factors on the kinetics of enzymes reaction.

## 5.2. Solve the tasks:

**Task 1.**Calculate the constant of the reaction rate A + B → AB, if the concentrations of substances A and B are equal to, respectively, 0,05 and 0,01 mol/l, and the reaction rate is $5\cdot10^{-5}$mol/l·min.

Answer: 0,1 l/mol·min

**Task 2.**Reaction between substances A and B is expressed by the equation: A + 2B → C. The initial concentrations are equal to: [A] = 0,03 mol/l, [B] = 0,05 mol/l. The constant of the reaction rate is 0,4 $l^2/mol^2\cdot s$. Calculate the initial rate of the reaction and the reaction rate in a certain time, when the concentration of A substance decreases by 0,01 mol/l.

Answer: $3,6\cdot10^{-5}$mol/l·s; $7,2\cdot10^{-6}$mol/l·s

**Task 3.**How will the rate of the direct reaction in the system $2N_2 + O_2 \rightarrow 2N_2O$, change if the volume of the system is decreased by a factor of tree?

Answer: The rate has is increased by 27

**Task 4.**How many times will the rate of the reaction increase, if the temperature has 30° increase ($\gamma = 2$)?

Answer: by 8.

## 5.3. Examples of the solved tasks:

**Task 1.** The rate constant of the reaction C + 2D → E is equal to 0.4 $l^2/mol^2\cdot s$. Concentrations of the reactants are equal to: [C] = 3 mol/l, [D] = 4 mol/l. Calculate the rate of the direct reaction.

***Solution.*** From the law of mass action, the reaction rate is equal:

$$\upsilon=k[C]\cdot[D]^2;$$

$\upsilon=0{,}4\cdot3\cdot4^2=19{,}2$ mol/l·s.

Answer: 19,2mol/l·s.

**Task 2.**How will the rate of the reaction $2NO + O_2 \rightarrow 2NO_2$ change, if the pressure in the system tripled?

***Solution.***From the law of mass action, the reaction rate is equal to:

$$\upsilon=k[NO]^2\cdot[O_2].$$

As the pressure triples the volume is decreased by a factor of tree 3, and the concentration triples. Then,

$\upsilon=k[3NO]^2\cdot[3O_2]=27k[NO]^2\cdot[O_2].$

$$\frac{\upsilon_2}{\upsilon_1}=\frac{27k[NO]^2\cdot[O_2]}{k[NO]^2\cdot[O_2]}=27.$$

Answer: the rate of the reaction is increased by 27

**Task 3.**How many times will the rate of the reaction increase, if the temperature has 50° increase ($\gamma = 2$)?

***Solution.***

$$\frac{\upsilon_2}{\upsilon_1} = \gamma^{\frac{t_2 - t_1}{10}} = 2^{\frac{50}{10}} = 2^5 = 32.$$

Answer: by 32

### 5.4. Study tests (p. 62).

## Literature:

1. Medical Chemistry : textbook / V. A. Kalibabchuk [and ol.] ; ed. by V. A. Kalibabchuk. - K. : Medicine, 2010. - p.37-49
2. LevitinYe.Ya. General and Inorganic Chemistry : textbook for students of higher schools / Ye. Ya.Levitin, I. A. Vedernikova. - Kharkiv : Golden Pages, 2009. - 360 p.
3. Inorganic Chemistry : textbook / ed.: D. F. Shriver, P. W. Atkins. - 3th ed. - [s. l.] : Oxford University Press, 2004. - 763 p.

## 6. LABORATORY WORK

### 6.1. Evaluation of dependence of reaction rate on reactant concentration

You need to take 3 dry tubes. Instill 5 drops of 1 N $Na_2S_2O_3$ solution into the first one, 10 drops – into the second and 15 drops into the third one. To achieve equal volumes in all three tubes you need to add 10 drops of d-water into the first tube and 5 drops into the second one. Thus, you'll get different concentration of $Na_2S_2O_3$ in the tubes. You'll code them as follows: c – the first tube, 2c – the second tube, 3c – the third tube.

Add to the first tube one drop of 1 M of solution of sulphiric acid ($H_2SO_4$) and start timing from the moment of adding the acid till the moment of opalescence, appearing, caused by sulphur separation:

$$Na_2S_2O_3 + H_2SO_4 \rightarrow Na_2SO_4 + S\downarrow + SO_2\uparrow + H_2O.$$

You need to carry out similar experiments with the second and the third tubes.

Evaluate the reaction rate in all three cases. Put down the results of the experiments into the table.

| № tube | Drops $Na_2S_2O_3$ | Drops $H_2O$ | Concentration, mole/l | Time of reaction process τ, c | Reaction rate υ, 1/τ, $s^{-1}$ |
|---|---|---|---|---|---|
| 1 | 5 | 10 | 0,33 | | |
| 2 | 10 | 5 | 0,66 | | |
| 3 | 15 | – | 1 | | |

Draw the chart of the dependence of the reaction rate on concentration of sodium thiosulphate v – f(C) and make conclusions.

## 6.2.Evaluation of reaction rate dependence on temperature

Instill 10 drops of 1 N $Na_2S_2O_3$ solution into the tube. Measure the room temperature. Add into the tube 1 drop of 1 M of sulphiric acid solution ($H_2SO_4$) and start timing from the moment of adding the acid till the moment of opalescence appearance.

Carry out similar experiments increasing the temperature each time by 10 ºC.

Put down the results of the experiments into the table and make conclusions about the effect of temperature on reaction rate.

| № tube | Drops, $Na_2S_2O_3$ | Temperature, ºC | Time of reaction process τ, c |
|---|---|---|---|
| 1 | 10 | | |
| 2 | 10 | | |
| 3 | 10 | | |

*Evaluate Vant-Hoff factor by formula:*

$$\gamma = \frac{\upsilon_{t_2}}{\upsilon_{t_1}}$$

## 7. TRAINING AND CONTROL MEANS

– table funds on the theme of the tutorial;

– card for determination of initial level of knowledge and skills;

–questions for review;

– tests.

# Tutorial № 13

**1. THEME: The chemical equilibrium. Solubility product**

**2. PUROSE: To learn to determine the direction of chemical reactions and to evaluate the effect of different factors on the behavior of chemical processes**

## 3. OBJECTIVIES:

3.1. To learn the basic concepts of chemical equilibrium.

3.2. To learn the Le Chatelier principle.

3.3. To learn to evaluate the effect of different factors on the chemical equilibrium.

## 4. PLAN AND ORGANIZATIONAL STRUCTURE OF THE TUTORIAL:

4.1. Organizational part…………………………………………5 min

4.2. Goal-setting and motivation of the theme studying (opening address of the teacher)……………………………. ………5 min

4.3. Determination of initial knowledge level…………………15 min

4.4. Correction of the initial knowledge level………..………..25 min

4.5. Organization of independent work of students (target teacher guidance, rules of accident prevention)……… ……………….5 min

4.6. Laboratory work……………………………….……….45 min

4.7. Final control: checking of the laboratory work results and protocols…………………………………………………....10 min

4.8. Concluding remarks of the teacher, instructional lines for the next lesson……………………………………………………......3 min

## 5. REFERENCE FOR SELF-STUDY:

## 5.1. Questions for self-study

1. The chemical equilibrium. The chemical equilibrium constant, ways of its expression.
2. Displacement of chemical equilibrium in the process of changing of temperature, pressure, substances concentration. LeChatelierprinciple.
3. Sedimentationreactions.
4. Solubility product, solubility, relation between them.
5. Conditions of formation and dissolution of sedimentations.
6. The role of heterogeneous equilibrium with the involvement of salts in general homeostasis of body.

## 5.2. Solve the tasks:

**Task 1.**The reaction proceeds according to the equation $2A \leftrightarrow B$. Equilibrium concentrations of substances is equal to: [A] = 0.2 mol/l, [B] = 0.3 mol/l. Calculate the equilibrium constant.

Answer: 7,5.

**Task 2.**In what direction will the reaction equilibrium $4HCl + O_2 \leftrightarrow 2H_2O + 2Cl_2$ shift, if the concentrations of all substances are doubled? Confirm the answer with the calculations.

Answer: in forward direction.

**Task 3.**Calculate the solubility product $PbCrO_4$, if its solubility is equal to $1{,}34 \cdot 10^{-7}$ mol/l.

Answer: $1{,}80\cdot 10^{-14}$.

## 5.3. Examples of the solved tasks:

**Task 1.**In the system $2NO + O_2 \leftrightarrow 2NO_2$ equilibrium concentrations of substances are equal to: [NO] = 0,15 mol/l, $[O_2]$ = 0,2 mol/l, $[NO_2]$ = 0,4 mol/l. Calculate the equilibrium constant.

***Solution.***For this system the equilibrium constant is equal to:

$$K_c = \frac{[NO_2]^2}{[NO]^2 \cdot [O_2]} = \frac{0{,}4^2}{0{,}15^2 \cdot 0{,}2} = 35{,}5\,.$$

Answer: 35,5.

**Задача 2.**The equilibrium in the system $2NO + O_2 \leftrightarrow 2NO_2$ is established at the following concentrations of substances: [NO] = 0,5 mol/l, $[O_2]$ = 0,7 mol/l, $[NO_2]$ = 2,1 mol/l. How will the chemical equilibrium change, if the pressure in the system is halved?

***Solution.*** The equilibrium constant before the pressure change is equal to:

$$K_{c_1} = \frac{[NO_2]^2}{[NO]^2 \cdot [O_2]} = \frac{2{,}1^2}{0{,}5^2 \cdot 0{,}7} = \frac{4{,}41}{0{,}175} = 25{,}2\,.$$

When the pressure is halved, the concentration of all substances also is halved. The equilibrium constant after the pressure change is equal to:

$$K_{c_2} = \frac{[NO_2]^2}{[NO]^2 \cdot [O_2]} = \frac{(0{,}5 \cdot 2{,}1)^2}{(0{,}5 \cdot 0{,}5)^2 \cdot 0{,}5 \cdot 0{,}7} = \frac{1{,}1025}{0{,}0219} = 50{,}4\,.$$

The equilibrium constants ratio is equal to:

$$\frac{K_{c_1}}{K_{c_2}} = \frac{25{,}2}{50{,}4} = 0{,}5\,.$$

Answer: the chemical equilibrium will shift in the direction of reverse reaction.

**Task 3.** Calculate the ionic product of $AgCrO_4$, if its solubility is equal to $6{,}5 \cdot 10^{-5}$ mol/l.

***Solution.*** $AgCrO_4$ is dissociated by equation:

$$AgCrO_4 \leftrightarrow Ag^+ + CrO_4^{2-}$$

The ions concentrations are equal to:

$[Ag^+] = 2 \cdot 6{,}5 \cdot 10^{-5} = 1{,}3 \cdot 10^{-4}$ mol/l;
$[CrO_4^{2-}] = 6{,}5 \cdot 10^{-5}$ mol/l.

IP $AgCrO_4 = [Ag^+]^2 \cdot [CrO_4^{2-}] = (1{,}3 \cdot 10^{-4})^2 \cdot 6{,}5 \cdot 10^{-5} = 1{,}1 \cdot 10^{-12}$.

Answer: $1{,}1 \cdot 10^{-12}$.

**5.4. Study tests (p. 71).**

## Literature:

1. Medical Chemistry : textbook / V. A. Kalibabchuk [and ol.] ; ed. by V. A. Kalibabchuk. - K. : Medicine, 2010. - p.49-54
2. LevitinYe.Ya. General and Inorganic Chemistry : textbook for students of higher schools / Ye. Ya.Levitin, I. A. Vedernikova. - Kharkiv : Golden Pages, 2009. - 360 p.

3. Inorganic Chemistry : textbook / ed.: D. F. Shriver, P. W. Atkins. - 3th ed. - [s. l.] : Oxford University Press, 2004. - 763 p.

## 6. LABORATORY WORK

### 6.1. Effect of reactant concentration on equilibrium displacement

Pour 50 ml d-water into the flask, add 1 drop of $FeCl_3$ saturated solution and 1 drop of $NH_4SCN$ saturated solution, mix everything. You will get a colored solution of ferrous thiocyanate:

$$FeCl_3 + 3NH_4SCN \leftrightarrow Fe(SCN)_3 + 3NH_4Cl$$

Put 10 ml the solution into each of 4 tubes. Add 2 drops of $FeCl_3$ saturated solution into the first tube, 2 drops of $NH_4SCN$ saturated solution - into the second, crystals of $NH_4Cl$ (on the point of a spatula) - into the third, the fourth one leave for comparison. Note the variation of coloring intensity in each case, comparing with the solution in the fourth tube. Put down the results of the experiments into the table:

| Tube | Added substance | Variation of coloring intensity | Directionof equilibriumdis placement |
|---|---|---|---|
| 1 | $FeCl_3$ | | |
| 2 | $NH_4SCN$ | | |
| 3 | $NH_4Cl$ | | |
| 4 | – | | |

Write down the expression of equilibrium constants of the given reversible chemical process. Apply Le Chatelier's principle to explain equilibrium displacement under condition of concentration of reactants changing.

## 6.2. Effect of temperature on equilibrium displacement

Put 2 ml of starch solution and add 1 drop of iodine solution into 2 tubes. Heat one of the tubes and then cool it down. Leave the second tube for comparison. Describe external effect. Make conclusions.

## 6.3. Displacement of equilibrium in the direction of slightly soluble combination formation

Put 2 ml of 0,5 M $SrCl_2$ solution and 2 ml of $CaSO_4$ saturated solution into the first tube. Put 4 ml of $CaSO_4$ saturated solution into the second tube. Heat both tubes on the water bath. Put down the results of the experiments into the table:

| Substance | SP | S, mole/l | Externaleffect observation |
|---|---|---|---|
| $SrSO_4$ | $3{,}2\cdot10^{-7}$ | $5{,}6\cdot10^{-4}$ | |
| $CaSO_4$ | $2{,}5\cdot10^{-5}$ | $5{,}0\cdot10^{-3}$ | |

Write chemical equation and make conclusions about displacement of equilibrium.

## 6.4. Displacement of equilibrium in the direction of slightly dissociated acid formation

Instill 5-6 drops of BaCl2 solution into 2 tubes. Then add 5-6 drops of Na2SO4 solution into the first tube and 5-6 drops of Na2CO3 solution into the second one.

Instill 10-12 drops of CH3COOH solution into the both tubes. Observe the difference in the formed slightly soluble salts behaviour with acetic acid. Write chemical equation and make conclusions about direction and conditions of equilibrium displacement:

## 7. TRAINING AND TESTING MEANS

– table funds on the theme of the tutorial;
– card for determination of initial level of knowledge and skills;
–questions for review;
– tests.

# Tutorial № 14

## 1. THEME: Evaluation of oxidation-reduction potential

**2. PURPOSE: Tolearntousetheviewsabouttheredoxpotentialsfortheexplanationofbiologicaloxidationinlivingorganisms**

## 3. OBJECTIVIES:

3.1. To learn to predict the direction of chemical and biochemical oxidation-reduction reactions.

3.2. To learntoapplypracticallytheoxidation-reductiontitrationandpotentiometricmethodsinbiomedicalresearch.

3.3. To learn to interpret the redox processes of living organisms for diagnostic and treatment.

## 4. PLAN AND ORGANIZATIONAL STRUCTURE OF THE TUTORIAL:

4.1. Organizational part……………………………………………………..5 min
4.2. Goal-setting and motivation of the theme studying (opening address of the teacher)…………………………… ………………………………………5 min
4.3. Determination of initial knowledge level………………………………15 min
4.4. Correction of the initial knowledge level……….……………………25 min
4.5. Organization of independent work of students (target teacher guidance, rules of accident prevention)……… ………………………………………………5 min
4.6. Laboratory work……………………………………….………………45 min
4.7. Final control: checking of the laboratory work results and protocols…………………………………………………..........................10 min

4.8. Concluding remarks of the teacher, instructional lines for the next lesson……………………………………………………………........................3 min

5. REFERENCE FOR SELF-STUDY:

### 5.1. Questions for self-study

1. Essence of oxidation-reduction reactions. What is the essence of oxidation and reduction process?
2. Electrode potentials and mechanism of their genesis.
3. Calculation of the electrodepotential (Nernstequation). Theconceptof a redoxcouple.
4. Howthevalueofthestandardredoxpotentialcharacterizestheredoxpropertiesoftheredoxcouple?
5. Opportunity, direction, and completeness of the redox reactions behaviours.
6. Diffusion and membrane potentials.The nature of biopotentials.
7. The meaning of redox and membrane potentials in biology and medicine.
8. Potentiometry, applicationinmedicineandsanitaryandhygienic practice.

### 5.2. Solve the tasks:

**Task 1.**At 298,15°K temperature the potential of hydrogen electrode, which is dipped into sample solution is equal to –0,118 V. Calculate pH and concentration of hydrogen ions of this solution.

Answer: pH = 2; $[H^+] = 10^{-2}$mol/l.

**Task 2.**Calculate the value of $E^0_{Ox/Red}$ at 18ºC, if $E_{p\ Ox/Red}$ = –0,15 V, and the system contains 60% of oxidation form and 30% of reduction form of the substances. Two electrons are disproportioned in the reaction.

Answer: 0,159 V.

## 5.3. Examples of the solved tasks:

**Task 1.** Calculate the ratio between the oxidized and reduced forms for the redox system $Fe^{3+}/Fe^{2+}$, if $E^0_{Fe^{3+}/Fe^{2+}} = 0{,}77\ V$, $E_{p\ Fe^{3+}/Fe^{2+}} = 0{,}888\ V$.

***Solution.***

$$Fe^{3+} + \bar{e} \leftrightarrow Fe^{2+}$$

The ratio betweenthe oxidized and reduced forms for redox couple $Fe^{3+}/Fe^{2}$ can be calculated with the help of the Nernst equation:

$$E_{p\ Fe^{3+}/Fe^{2+}} = E^0_{Fe^{3+}/Fe^{2+}} + \frac{0{,}059}{n} \cdot \lg\frac{[Fe^{3+}]}{[Fe^{2+}]}$$

Substituting the known data, we find the ratio $\frac{[Fe^{3+}]}{[Fe^{2+}]}$:

$$0{,}888 = 0{,}77 + \frac{0{,}059}{1} \cdot \lg\frac{[Fe^{3+}]}{[Fe^{2+}]};$$

$$\lg\frac{[Fe^{3+}]}{[Fe^{2+}]} = \frac{0{,}888 - 0{,}77}{0{,}059} = 2;$$

$$\frac{[Fe^{3+}]}{[Fe^{2+}]} = 100.$$

Answer: 100.

**Task 2.** For determination of the blood pH we recomposed the galvanic element of silver chloride and hydrogen electrodes and measured EMF, which amounted to 0,635 V at the temperature of 298 K. The potential of silver chloride electrode is 0,201 V. Calculate the blood pH.

***Solution.*** The blood pH can be calculated from the equation of the electrode potential for the hydrogen electrode:

$$E_{2H^+|H_2\uparrow} = -0{,}059pH \text{, so } pH = \frac{E_{2H^+/H_2\uparrow}}{-0{,}059}.$$

The value $E_{2H^+|H_2\uparrow}$ can be easily calculated from the formula for calculating the EMF:

$$EMF = E_{Ag|AgCl,KCl} - E_{2H^+|H_2\uparrow},$$

$$0{,}635 = 0{,}201 - E_{2H^+|H_2\uparrow},$$

$$E_{2H^+|H_2\uparrow} = -0{,}434\,V.$$

So: $$pH = \frac{E_{2H^+/H_2\uparrow}}{-0{,}059} = \frac{-0{,}434}{-0{,}059} = 7{,}36.$$

Answer: pH = 7,36.

### 5.4. Study tests (p. 78).

## Literature:

1. Medical Chemistry : textbook / V. A. Kalibabchuk [and ol.] ; ed. by V. A. Kalibabchuk. - K. : Medicine, 2010. - p.92-107

2. LevitinYe.Ya. General and Inorganic Chemistry : textbook for students of higher schools / Ye. Ya.Levitin, I. A. Vedernikova. - Kharkiv : Golden Pages, 2009. - 360 p.

3. Inorganic Chemistry : textbook / ed.: D. F. Shriver, P. W. Atkins. - 3th ed. - [s. l.] : Oxford University Press, 2004. - 763 p.

## 6. LABORATORY WORK

### 6.1. Evaluation of weight percent (%) of potassium iodide solution

Method – direct titration

Separate accurate weights technique.

Electrodes – silver-silver chloride (standard)

platinum (indicative).

*Химизмреакции:*

$2MnO_4^- + 10I^- + 16H^+ \leftrightarrow 2Mn^{2+} + 5I_2 + 8H_2O$

2 $MnO_4^- + 8H^+ + 5\bar{e} \leftrightarrow 2Mn^{2+} + 4H_2O$

5 $2I^- - 2\bar{e} \leftrightarrow I_2$

*Preliminary calculations:*

M(KI)= 166,0 g/mol;

fэ(KI)= 1;

Mэ(KI)= fэ(KI) ·M(KI) = 166,0 · 1 = 166,0 g/mol.

Put 5,00 ml of potassium iodide solution into the bunsen beaker (volume – 50 ml) and add 7,5 ml 1 M of sulfuric acid solution. Place the bunsen beaker on the table of magnetic stir bar, douse the electrodes and titrate it with 0,1000 N of potassium permanganate under continuous stirring. Register real oxidation-reduction potential with the help of universal ionomerЭВ-74 using the system of electrodes: indicative-platinum, standard - silver-silver chloride.

The first titration – is approximate (rough).

In the process of titration the reactant (0,1000 N of $KMnO_4$ solution) is added by 1,00 ml. After the titrant has been added, mix the solution with the help of magnetic stir for 30 s and register the value of oxidation-reduction potential.

The second titration – is exact.

Before the start of the difference of redox-potential in the defined system add the titrant (0,1000 N $KMnO_4$ solution) by 1,00 ml. And within the difference of potential – by 0,10 ml. It gives the possibility to registers accurately the equivalence point of the carried-out titration.

Put down the results of the experiments into the table:

| $V(KMnO_4)$, ml | $E_p$, mV | ΔV, ml | ΔE, mV | ΔE/ΔV |
|---|---|---|---|---|
| | | | | |

Use the results of potentiometric titration for graphing of a differential curve of titration.

Find out the volume of potassium permanganate which was consumed for titration of sample solution using the curve of titration and calculate weight percent (%) of potassium iodide in the solution by formula:

$$\omega_{(KI)} = \frac{V_{(KMnO_4)} \cdot C_{(KMnO_4)} \cdot K_{п} \cdot M_{Э(KI)} \cdot 100}{a_{(KI)} \cdot 1000}.$$

## 7. TRAINING AND TESTING MEANS

– table funds on the theme of the tutorial;

– card for determination of initial level of knowledge and skills;

–questions for review;

– tests.

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# TEST QUESTIONS

## Tests for tutorial № 11

1. When the isobaric-isothermal processes proceed the following values remain constant (const):

A. Temperature.

B. Temperature and pressure.*

C. Volume.

D. Volume and temperature.

2. How will the entropy of irreversible phase transition change:

$Hg_{(l.)} \rightarrow Hg_{(g)}$?

A. ΔS>0.*

B. ΔS<0.

C. ΔS=0.

3. How will the entropy of irreversible phase transition change:

$I_{2(g)} \rightarrow I_{2(g)}$?

A. ΔS>0.

B. ΔS<0.*

C. ΔS=0.

4. How will the entropy in the following reaction change:

$3H_{2(g)} + N_{2(g)} \rightarrow 2NH_{3(g)}$?

A. ΔS>0.

B. ΔS<0.*

C. ΔS=0.

5. How will the entropy in the following reaction change:

$NH_4NO_{3(c)} \rightarrow N_2O_{(g)} + 2H_2O_{(g)}$?

A. $\Delta S>0$.*

B. $\Delta S<0$.

C. $\Delta S=0$.

6. How will the entropy in the following reaction change:

$3H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(g)}$?

A. $\Delta S>0$.

B. $\Delta S<0$.*

C. $\Delta S=0$.

7. Choose the mathematical expression of the thermodynamic function called Gibbs energy:

A. $Q = \Delta U + A$

B. $\Delta H_{react.} = \sum \Delta H^{\circ}_{form.prod.} - \sum \Delta H^{\circ}_{form.init.subst.}$

C. $\Delta S = \frac{\Delta Q}{T}$

D. $\Delta G = \Delta H - T\Delta S$*

E. $S = k \cdot \ln W$

8. In homogenous systems:

A. There are interphases.

B. There aren’t interphases. *

C. Its properties are different at all points.

9. In heterogeneous systems:

A. There are interphases. *

B. There aren’t interphases.

C. Its properties are different at all points.

10. The human body is ______system:

A. Homogeneous.

B. Biphasic.

C. Heterogeneous.*

D. Monophasic.

11. Isolated thermodynamic system communicates with the environment:

A. Through mass and energy.

B. Through energy.

C. Does not exchange either mass or energy. *

D. Through mass.

12. Closed thermodynamic system communicates with the environment:

A. Through mass and energy.

B. Through energy. *

C. Does not exchange either mass or energy.

D. Through mass.

13. Open thermodynamic system communicates with the environment:

A. Through mass and energy.*

B. Through energy.

C. Does not exchange either mass or energy.

D. Through mass.

14. The living organism is a _____system:

A. Open.*

B. Closed.

C. Homogeneous.

D. Isolated.

15. Extensive parameters are:

A. Temperature.

B. Concentration.

C. Pressure.

D. Mass.*

E. Density.

16. Extensive parameters are:

A. Concentration.

B. Energy.*

C. Pressure.

D. Temperature.

E. Density.

17. Extensive parameters are:

A. Pressure.

B. Density.

C. Concentration.

D. Temperature.

E. Volume.*

18. Extensive parameters are:

A. Heat capacity.*

B. Density.

C. Concentration.

D. Temperature.

E. Pressure.

19. Intensive parameters are:

A. Energy.

B. Heat capacity.

C. Pressure.*

D. Mass.

E. Volume.

20. Intensive parameters are:

A. Density.*

B. Heat capacity.

C. Energy.

D. Mass.

E. Volume.

21. Intensive parameters are:

A. Mass.

B. Heat capacity.

C. Energy.

D. Concentration.*

E. Volume.

22. Intensive parameters are:

A. Mass.

B. Heat capacity.

C. Temperature.*

D. Energy.

E. Volume.

23. The human body can considered as the system with the following processes proceeding:

A. Isobaric.

B. Isothermic.

C. Isochoric-isothermic.

D. Isobaric-isothermic.*

E. Isochoric.

24. Internal energy of system depends on:

A. Differences of system position.

B. Nature of the system motion.

C. System parameters.*

25. Internal energy of system doesn’t depend on:

A. Composition.

B. Nature of the system motion. *

C. Temperature.

D. Pressure.

26. The thermal effect of the chemical reaction, which carried out under constant pressure, is called the change of:

A. Internal energy.

B. Enthalpy.*

C. Entropy.

27. The thermal effect of chemical reaction in isochoric process is equal to change of:

A. Internal energy.*

B. Enthalpy.

C. Entropy.

28. With what values of $\Delta H$ do the exothermal processes proceed:

A. $\Delta H>0$.

B. $\Delta H<0$.*

C. $\Delta H=0$.

29. With what values of $\Delta H$ do the endothermic processes proceed:

A. $\Delta H>0$.*

B. $\Delta H<0$.

C. $\Delta H=0$.

30. Why does anhydrous salt dissolve with heat release:

A. Because dissolution occurs due to the exothermic process of hydration.*

B. Because, dissolution occurs due to the endothermic process of chemical bonds opening into the crystal.

C. Because anhydrous salts dissolve worse.

D. Because anhydrous salts dissolve better.

31. Why does crystallohydrate dissolve with heat absorption:

A. Because dissolution occurs due to the exothermic process of hydration.

B. Because, dissolution occurs due to the endothermic process of chemical bonds opening into the crystal.*

C. Because crystallohydrates dissolve worse.

D. Because crystallohydrates dissolve better.

32. What system tendency does the entropy factor express:

A. Tendency towards the energy minimum.

B. Tendency towards the disorder maximum.*

C. Tendency towards the equilibrium achievement.

33. Entropy is the thermodynamics function, which characterizes:

A. The aggregate state of the system.

B. The heat content of the system.

C. The random arrangement of particles in the system.*

D. The store of the internal energy in the system.

34. The spontaneous nature of the process is best determined by evaluating the change of:

A. Temperature.
B. Gibbs energy.*
C. Enthalpy.
D. Entropy.

35. The criterion of the spontaneous occurrence of any process is:

A. Increase of entropy.
B. Decrease of Gibbs energy.*
C. Decrease of entropy.
D. Increase of Gibbs energy.

36. Each open system tends to have its energy ____:

A. Constant.
B. Minimum.*
C. Maximum.

37. How does the entropy change with the increase of temperature:

A. Increase.*
B. Decrease.
C. Doesn’t change.

38. How does the entropy change with the increased of pressure:

A. Increase.
B. Decrease. *
C. Doesn’t change.

39. With what value of ΔG will the reaction $COC1_2 \rightarrow CO + C1_2$ proceed spontaneously in the forward direction:

A. –12,8kJ/mol.*

B. +2,9 kJ/mol.

C. 0.

40. The endergonic reactions ($\Delta G^{\circ\prime} > 0$) in the human body:

A. Can't proceed.

B.Possible only due to the participation of enzymes.

C. Possible only when coupling with exergonic processes.*

41. What formula is the mathematical expression of the first consequence of the Hess's law:

A. $\Delta H_1 = \Delta H_2 + \Delta H_3$

B. $\Delta H = \sum \Delta H^{\circ}_{f.prod.} - \sum \Delta H^{\circ}_{f.react}$

C. $\Delta H_{forw.} = -\Delta H_{rev.}$*

D. $\Delta H = \sum \Delta H^{\circ}_{c.react.} - \sum \Delta H^{\circ}_{c.prod.}$

E. $\Delta H = \Delta G + T\Delta S$

42. What formula is the mathematical expression of the second consequence of the Hess's law:

A. $\Delta H = \Delta G + T\Delta S$

B. $\Delta H = \sum \Delta H^{\circ}_{f.prod.} - \sum \Delta H^{\circ}_{f.react}$ *

C. $\Delta H = \Delta U + p\Delta V$

D. $\Delta H = \sum \Delta H^{\circ}_{c.react.} - \sum \Delta H^{\circ}_{c.prod.}$

E. $\Delta H_1 = \Delta H_2 + \Delta H_3$

43. What formula is the mathematical expression of the third consequence of the Hess's law:

A. $\Delta H = \Delta G + T\Delta S$

B. $\Delta H= \sum\Delta H^{\circ}_{f.prod.}-\sum\Delta H^{\circ}_{f.react.}$

C. $\Delta H_1 = \Delta H_2 + \Delta H_3$

D. $\Delta H= \sum\Delta H^{\circ}_{c.react.}-\sum\Delta H^{\circ}_{c.prod.}$ *

E. $\Delta H = \Delta U + p\Delta V$

44. What formula is the mathematical expression of the Hess’s law:

A. $\Delta H =\Delta G + T\Delta S$

B. $\Delta H= \sum\Delta H^{\circ}_{f.prod.}-\sum\Delta H^{\circ}_{f.react.}$

C. $\Delta H_1 = \Delta H_2 + \Delta H_3$*

D. $\Delta H= \sum\Delta H^{\circ}_{c.react.}-\sum\Delta H^{\circ}_{c.prod.}$

E. $\Delta H = \Delta U + p\Delta V$

45. The entropy of a system is a measure of its:

A. Reversibility.

B. Heat capacity.

C. Disorder.*

D. Thermal effect.

46. The enthalpy of a system is a measure of its:

A. Reversibility.

B. Heat capacity.*

C. Disorder.

D. Thermal effect.

47. The entropy of a pure crystal at absolute zero is equal to:

A. +1.

B. –1.

C. 0.*

D. ∞.

48. The standard thermodynamic quantities characterize the system state at the following values of temperature and pressure:

A. $t = 0^oC$, p = 1 atm.

B. $t = 20^oC$, p = 101,3 kPa.

C. $T = 298^oK$, p = 101,3 kPa.*

D. $T = 273^oK$, p = 101,3kPa.

49. Choose the mathematical expression of the first law of thermodynamics:

A. $S = k \cdot \ln W$

B. $\Delta H = \sum \Delta H^{\circ}_{f.prod..} - \sum \Delta H^{\circ}_{f.react.}$

C. $\Delta S = \frac{\Delta Q}{T}$

D. $\Delta G = \Delta H - T\Delta S$

E. $Q = \Delta U + A$*

50. Choose the mathematical expression of the first law of thermodynamics:

A. $S = k \cdot \ln W$

B. $\Delta H = \sum \Delta H^{\circ}_{f.prod..} - \sum \Delta H^{\circ}_{f.react.}$

C. $\Delta H = \sum \Delta H^{\circ}_{c.react.} - \sum \Delta H^{\circ}_{c.prod.}$

D. $\Delta G = \Delta H - T\Delta S$

E. $\Delta U = Q - A$*

## Tests for tutorial № 12

1. The chemical reaction rate is the change of:

A. Concentration of one of the reactants per unit of time.*

B. Pressure per unit of time.

C. Volume of one reactant per unit of time.

2. According to the rule of the van't Hoff the 10°C temperature increase causes the following change of the chemical reaction rate:

A. Decrease by 2-4.
B. Increase by 2-4.*
C. Decrease by 1,5-2.
D. Increase by 1,5-2.

3.In competitive reactions:

A. One reaction speeds up the proceeding of the other reaction.
B. One reaction hinders the proceeding of the other reaction.*
C. Two reactions proceed simultaneously.

4.In autocatalysis:

A. The catalyst is one of the initial substances.
B. The catalyst is platinum.
C. The catalyst is one of the reaction products.*

5.Molecularity of the reaction is called:

A. The sum of the exponents in the kinetic equation.
B. The number of particles involved in an elementary act of the reaction.*
C. The phenomenon of participation only of molecules in an elementary act.
D. The transformation of the reactants ions in the product molecules.

6. How will the chemical reaction rate $2H_2 + O_2 \rightarrow 2H_2O$ change if hydrogen concentration is increased by 2?

A. Increase by 2.
B. Increase by 8.
C. Increase by 16.
D. Increase by 4.*
E. Decrease by 4.

7. How will the rate of direct reaction $2SO_2 + O_2 \rightarrow 2SO_3$ change if $SO_2$concentration is increased by 3?

A. Increase by 3.

B. Increase by 9.*

C. Increase by 27.

D. Decrease by 3.

E. Will not change.

8. How will the rate of a chemical reaction change at the temperature increasing from 20ºC to 50ºC if the temperature factor is 2?

A. Increase by 2.

B. Increase by 4.

C. Increase by 6.

D. Increase by 8.*

E. Decrease by 4.

9.With the increasing temperature, the number of active molecules:

A. Doesn’t change.

B. Increases.*

C. Decreases.

10. Antioxidants are substances that:

A. Bind free radicals.*

B. Bind metabolites..

C. Strengthen the redox reactions..

11. The chemical reaction proceeding $2CO + O_2 \rightarrow 2CO_2$ is described with the following expression of the mass action law:

A. $\upsilon = k \cdot [CO_2]$

B. $\upsilon = k\cdot[CO]\cdot[O_2]$

C. $\upsilon = k\cdot[CO]^2\cdot[O_2]$*

D. $\upsilon = k\cdot[CO_2]^2$

E. $\upsilon = k\cdot[CO]^2\cdot[O_2]\cdot[CO_2]$

12. The total order of the reaction in the kinetic equation $\upsilon=k\cdot[CO]^2\cdot[O_2]$ is equal to:

A. 0.

B. 1.

C. 2.

D. 3.*

13 The order of the reaction by CO in the kinetic equation $\upsilon=k\cdot[CO]^2\cdot[O_2]$ is equal to:

A. 0.

B. 1.

C. 2.*

D. 3.

14. The order of the reaction by $O_2$in the kinetic equation $\upsilon=k\cdot[CO]^2\cdot[O_2]$ is equal to:

A. 0.

B. 1.*

C. 2.

D. 3.

15. The reaction has zero$^{th}$ order. How does the reaction rate change at a time at a constant temperature?

A. Increases.

B. Decreases.

C. Remains constant.*

16. How does the activation energy in the catalytic processchange?

A. Decreases.*

B. Increases.

C. Doesn’t change.

D. Increases gradually.

E. Decreases gradually**.**

17. The chemical reaction rate are characterized by:

A. Changing of the amount of substances per unit of time in terms of volume or area.*

B. The time in which a chemical reaction completes.

C. The number of molecules of the substance participated in chemical reactions.

D. Motion of the molecules of the reactants relatively to each other.

18. For chemical process $FeO_{(c)} + H_{2(g)} \rightarrow Fe_{(c)} + H_2O_{(f)}$ point out how many times the rate of the direct reaction decreases with the decreasing of the hydrogen concentration by 3?

A. By 3.*

B. By 6.

C. By 9.

D. By 27.

19.How many times will the reaction rate $2A + B \rightarrow 2C$ change, if the concentration of A substance decreases by 2?

A. Increases by 4.

B. Decreases by 4.*

C. Increases в by.

D. Decreases by 2.

20. Enzymes are biocatalysts, which have:

A. Carbohydrate nature.

B. Lipid nature.

C. Protein nature.*

21. Catalysis is called heterogeneous, if reactants and catalyst:

A. Are in the different phases.*

B. Are in the same phase .

C. Are at a constant temperature.

D. Are at different pressures.

22. Catalysis is called homogeneous, if reactants and catalyst:

A. Are in the different phases.

B. Are in the same phase.*

C. Are at a constant temperature.

D. Are at different pressures.

23. The reaction $C_{(c)} + CO_{2(g)} \rightarrow 2CO_{(g)}$ is followed expression of the mass action law:

A. $\upsilon = k \cdot [CO_2]$*

B. $\upsilon = k \cdot [C] \cdot [CO_2]$

C. $\upsilon = k \cdot [C] \cdot [CO_2] \cdot [CO]^2$

D. $\upsilon = k \cdot [CO_2]^2$

E. $\upsilon = k \cdot [C] \cdot [CO_2] \cdot [CO]$

24. How will the direct reaction rate $C_{(c)} + CO_{2(g)} \rightarrow 2CO_{(g)}$change if reactants concentrations is increased by 2?

A. Increase by 4.

B. Increase by 8.

C. Increase by 2.*

D. Decrease by 2.

E. Will not change.

25. The rate of direct reaction $N_2 + 3H_2 \rightarrow 2NH_3$ increases with:

A. The increasing of the nitrogen concentration.*

B. The decreasing of the nitrogen concentration.

C. The increasing of the ammonia concentration.

D. Constant hydrogen concentration.

26. With the introduction of the catalyst in the system the rate of chemical processes are increased by:

A.The increasing of molecules kinetic energy.

B. The increasing of the collisions number.

C. The decreasing of the active molecules number.

D. The decreasing of the activation energy of the process.*

27. Mass action law establishes the dependence of the reaction rate on:

A. The temperature.

B. The chemical nature of the reactants.

C. The concentration of the reactants.*

D. The catalyst of the process.

28. How many times will the reaction rate occurring in the gas phase increase, if the temperature of the process is increased by 30 degrees and the temperature coefficient of the reaction rate is equal to 2?

A.By 2.

B. By 16.

C. By 8.*

D. By 4.

29. The basic concept of chemical kinetics is the chemical reaction rate. Designate how the chemical reaction rate at constant volume system is expressed in the general form:

A.P = CRT

B. Q = ΔU + A

C. ΔS = ΔQ/T

D. υ = ±ΔC/Δτ*

30. Designate the kinetic equation in general form for first-order reactions:

A.υ = k

B. υ = k·[A]*

C. υ = k·[A]·[B]

D. υ = k·$[A]^2$·[B]

31. Designate the kinetic equation in general form for second-order reactions:

A.υ = k

B. υ = k·[A]

C. υ = k·[A]·[B]*

D. υ = k·$[A]^2$·[B]

32. Designate the kinetic equation in general form for third-order reactions:

A.υ = k.

B. υ = k·[A].

C. υ = k·[A]·[B].

D. υ = k·$[A]^2$·[B].*

33. Designate the kinetic equation in general form for zero-order reactions:

A.υ = k*

B. υ = k·[A]

C. $\upsilon = k \cdot [A] \cdot [B]$

D. $\upsilon = k \cdot [A]^2 \cdot [B]$

34. Designate the kinetic equation for the reaction in which the general order of the reaction and the reaction order for this reagent are the same:

A.$\upsilon = k \cdot [A] \cdot [B]^2$

B. $\upsilon = k \cdot [A]$*

C. $\upsilon = k \cdot [A] \cdot [B]$

D. $\upsilon = k \cdot [A]^2 \cdot [B]$

35. The order of the reaction by A substance in the kinetic equation $\upsilon = k \cdot [A]^x \cdot [B]^y$ is equal to:

A.[A].

B. x.*

C. y.

D. x+y.

36. The order of the reaction by B substance in the kinetic equation $\upsilon = k \cdot [A]^x \cdot [B]^y$ is equal to:

A.[B].

B. x.

C. y.*

D. x+y.

37. The general order of the reaction in the kinetic equation $\upsilon = k \cdot [A]^x \cdot [B]^y$ is equal to:

A.[A]·[B].

B. x.

C. y.

D. x+y.*

38. Designate how many times the chemical reaction rate will increase with increasing of the temperature by 10°C:

A.By 5.
B. By 2-4.*
C. By 5-6.
D. 0,1-0,5.

39. The kinetic equation of the reaction $\upsilon = k\cdot[A]\cdot[B]$. Designate how many times the chemical reaction rate will decrease with decreasing concentration of the reactants by 3:

A.3.
B. 9.*
C. 27.
D. 81.

40. The kinetic equation of the reaction $\upsilon = k\cdot[A]^2\cdot[B]$. Designate how many times the chemical reaction rate will decrease with decreasing concentration of the reactants in 2 times:

A.2.
B. 4.
C. 8.*
D. 16.

41. The general order of the reaction in the kinetic equation $\upsilon = k\cdot[NO]^2\cdot[O_2]$ is equal to:

A.0.
B. 1.
C. 2.
D. 3.*

42. The order of the reaction by NO in the kinetic equation $\upsilon = k\cdot[NO]^2\cdot[O_2]$ is equal to:

A.0.

B. 1.

C. 2.*

D. 3.

43. The order of the reaction by $O_2$ in the kinetic equation $\upsilon = k\cdot[NO]^2\cdot[O_2]$ is equal to:

A.0.

B. 1.*

C. 2.

D. 3.

44. Catalyst poison is a substance that in small amounts

A.Decreases the catalyst activity.*

B. Increases the catalyst activity.

C. Doesn’t change the catalyst activity.

D. First increases and then decreases the catalyst activity.

45. Promoter (activator) is a substance that in small amount:

A.Decreases the catalyst activity.

B. Increases the catalyst activity.*

C. Doesn’t change the catalyst activity.

D. First increases and then decreases the catalyst activity.

46. The substance which decreases the chemical reaction rate is called:

A.Promoter.

B. Inhibitor.*

C. Catalyst.

47. The kinetic equation $\upsilon = k$ corresponds to the reaction of:

A.The third order.

B. The first order.

C. The second order.

D. The zero order.*

48. The kinetic equation $\upsilon = k\cdot[A]$ corresponds to the reaction of:

A.The third order.

B. The first order.*

C. The second order.

D. The zero order.

49. The kinetic equation $\upsilon = k\cdot[A]\cdot[B]$ corresponds to the reaction of:

A.The third order.

B. The first order.

C. The second order.*

D. The zero order.

50. The catalyst increases the chemical reaction rate, because it:

A.Decreases the activation energy.*

B. Increases the activation energy.

C. Doesn’t change the activation energy.

D. First increases and then decreases the activation energy.

51. The units of the chemical reactions rate are:

A.l/mol·s.

B. mol/l.

C. l/mol.

D. mol/l·s.*

52. Designate the units in which the measured rate constant of zero order reaction:

A.l/mol·s.
B. mol/l.
C. l/mol.
D. mol/l·s.*

53. Designate the units in which the measured rate constant of first order reaction:

A.l/mol·s.
B. $s^{-1}$.*
C. l/mol.
D. mol/l·s.

54. Designate the units in which the measured rate constant of second order reaction:

A.l/mol·s.*
B. $s^{-1}$.
C. l/mol.
D. mol/l·s.

55. The rate of enzymatic reactions with the increasing of temperature:

A.Doesn’t change.
B. Decreases.
C. Increases.
D. First increases and then decreases.*
E. First decreases and then increases.

## Tests for tutorial № 13

1. If the concentration of the initial substances in the equilibrium state is much higher concentration of products that:

A. $К_{equil.} >> l$.

B. $К_{equil.} << 1$.*

C. $К_{equil.} = 0$.

D. $К_{equil.} = 1$.

2. In the system AB ↔ A + B the concentration of the initial substances is smallest, if the value of the equilibrium constants is equal to:

A. 0,5.

B. 1.

C. 2.

D. 4.*

3. The equilibrium constant of the reaction: $2HC1 \leftrightarrow H_2 + C1_2$at a some temperature is equal to 40. Which substances concentration in equilibrium state is higher?

A. Initial substances.

B. Product.*

C. Are the same.

4. In what direction will displace the equilibrium of chemical reaction: $N_{2(g)} + O_{2(g)} \leftrightarrow 2NO_{(g)}$ if the pressure is increased?

A. To direction of the direct reaction.

B. To direction of reverse reaction.

C. Displacement of equilibrium will not happen.*

5. In the moment of chemical equilibrium $\Delta G$ of the reaction:

A.$\Delta G > 0$.

B. $\Delta G = 0$.*

C. $\Delta G < 0$.

6. In what direction will the equilibrium of chemical reaction: $CO_{2(g)} + C_{(g)} \leftrightarrow 2CO_{(g)}$ ($\Delta H = +171$ kJ) displace if the temperature is increased?

A.To the right.*

B. To the left.

C. Will not displace.

7. In what direction will the equilibrium of chemical reaction: $4NH_{3(g)} + 5O_{2(g)} \leftrightarrow 4NO_{(g)} + 6H_2O_{(f)}$ displace if the pressure is increased?

A.To the right.*

B. To the left.

C. Will not displace.

8. In what direction will the equilibrium of chemical reaction: $2CO_{2(g)} \leftrightarrow 2CO_{(g)} + O_{2(g)}$ ($\Delta H = +567{,}8$ kJ) displace if the temperature is decreased?

A.To the right.

B. To the left.*

C. Will not displace.

9. In what direction will the equilibrium of chemical reaction: $H_2 + Cl_2 \leftrightarrow 2HCl$ ($\Delta H = –91{,}8$ kJ) displace if the temperature is decreased?

A.To the right.*

B. To the left.

C. Will not displace.

10. In what direction will the equilibrium of chemical reaction: $2SO_{2(g)} + O_{2(g)} \leftrightarrow 2SO_{3(g)}$displace if the pressure is decreased?

A.To the right.

B. To the left.*

C. Will not displace.

11. The equilibrium of the heterogeneous system $C_{(c)} + CO_{2(g)} \rightarrow 2CO_{(g)}$ displaces to the initial substances direction by:

A.Increasing of the pressure.*

B. Increasing of the system volume.

C. Decreasing of the CO concentration.

D. Increasing of the $CO_2$ concentration.

12. For which of the mentioned processes the change of pressure will not cause displacement of chemical equilibrium:

A.$2NO_{(g)} + Cl_{2(g)} \leftrightarrow 2NOCl_{(g)}$

B. $S_{(c)} + O_{2(g)} \leftrightarrow SO_{2(g)}$*

C. $N_{2(g)} + 3H_{2(g)} \leftrightarrow 2NH_{3(g)}$

13. In what direction will the equilibrium of chemical reaction: $CH_{4(g)} + 2H_2O_{(g)} \leftrightarrow CO_{2(g)} + 4H_{2(g)}$ displace if the pressure is decreased?

A.To the right.*

B. To the left.

C. Will not displace.

14. In what direction will the equilibrium of chemical reaction: $H_2 + I_2 \leftrightarrow 2HI$ ($\Delta H = –51{,}8$ kJ) displace if the temperature is increased?

A.To the right.

B. To the left.*

C. Will not displace.

15. There is a chemical balance in the system $2SO_{2(г)} + O_{2(г)} \leftrightarrow 2SO_{3(г)}$ ($\Delta H<0$) The change of what parameter can force the displacement of the equilibrium in the direction of $SO_2$ formation ?

A.Increasing of $O_2$concentration.

B. Decreasing of the temperature.

C. Increasing of the temperature.*

D. Increasing of the pressure.

16. There is a chemical equilibrium in the system $CaCO_{3(т)} \leftrightarrow CaO_{(т)} + CO_{2(г)}$ ($\Delta H>0$). The change of what parameter can force the displacement of the equilibrium in the direction of CaO formation?

A.Increasing of $CO_2$ concentration.

B. Decreasing of the temperature.

C. Increasing of the temperature.*

D. Increasing of the pressure.

17. There is a chemical equilibrium in the system $2HI_{(g)} \leftrightarrow I_{2(g)} + H_{2(g)}$ ($\Delta H<0$) The change of what parameter can force the displacement of the equilibrium in the direction of HI formation?

A.Increasing of the temperature.*

B. Decreasing of the temperature.

C. Increasing of HI concentration.

D. Increasing of the pressure.

18. With what value of $K_{equil.}$do the reversible reactions proceed with the fullest transubstantiation of the initial substances into products?

A.$K_{equil.} = 1$.

B. $K_{equil.} < 1$.

C. $K_{equil.} > 1$.*

D. $K_{equil.} = 0$.

19. For the reversible reaction of hemoglobin binding of $Hb + O_2 \leftrightarrow HbO_2 K_{equil.}$ is equal to 1300 at 37°C. What is the direction of the reaction displacement?

A. To the right.*

B. To the left .

C. Doesn’t displace .

20. There is a chemical equilibrium in the system $Fe_3O_4 + 4H_{2(g)} \leftrightarrow 3Fe_{(c)} + 4H_2O_{(g)}$ ($\Delta H>0$) The change of what parameter can force the displacement of the equilibrium in the direction of Fe formation?

A.Decreasing of the pressure.

B. Decreasing of the temperature.

C. Increasing of the temperature.*

D. Increasing of the pressure.

21. There is a chemical equilibrium in the system $2SO_{2(g)} + O_{2(g)} \leftrightarrow 2SO_{3(g)}$ ($\Delta H<0$) The change of what parameter can force the displacement of the equilibrium in the direction of $SO_3$ formation?

A.Decreasing of the pressure.

B. Decreasing of the temperature.*

C. Increasing of $SO_3$ concentration.

D. The catalyst adding.

22. What the equations of the chemical equilibrium constant for the reaction $2PbS_{(c)} + 3O_{2(g)} \leftrightarrow 2PbO_{(c)} + 2SO_{2(g)}$ will be correct?

A. $K_e = \frac{[O_2]^3}{[SO_2]^2}$

B. $K_e = \frac{[O_2]^3 \cdot [PbS]^2}{[SO_2]^2 \cdot [PbO]^2}$

C. $К_e = \frac{[SO_2]^2}{[O_2]^3}$ *

D. $К_e = \frac{[SO_2]^2 \cdot [PbO]^2}{[O_2]^3 \cdot [PbS]^2}$

23. There is a chemical equilibrium in the system $NH_4Cl_{(c)} \leftrightarrow NH_{3(g)} + HCl_{(g)}$ ($\Delta H>0$). The change of what parameter can force the displacement of the equilibrium in the direction of $NH_4Cl$ formation?

A.Increasing of the pressure.

B. Decreasing of the temperature.*

C. Increasing of the temperature.

D. The catalyst adding.

24. There is a chemical equilibrium in the system $NH_4Cl_{(c)} \leftrightarrow NH_{3(g)} + HCl_{(g)}$ ($\Delta H>0$) The change of what parameter can force the displacement of the equilibrium in the direction of $NH_3$ formation?

A.Increasing of the pressure.

B. Decreasing of the temperature.

C. Increasing of the temperature.*

D. The catalyst adding.

25. What the equations of the chemical equilibrium constant for the reaction $CO_{(g)} + 2H_{2(g)} \leftrightarrow CH_3OH_{(g)}$ will be correct?

A. $Кe = \frac{[CH_3OH]}{[CO] \cdot [H_2]^2}$ *

B. $Кe = \frac{[CH_3OH]}{[CO]^2 \cdot [H_2]}$

C. $Кe = \frac{[CH_3OH]}{[CO] + [H_2]^2}$

D. $Кe = \frac{[CO][H_2]^2}{[CH_3OH]}$

26. What the equations of the chemical equilibrium constant for the reaction $C_{(c)} + H_2O_{(g)} \leftrightarrow CO_{(g)} + H_{2(g)}$ will be correct?

A. $K_e = [CO] \cdot [H_2]$

B. $K_e = \frac{[CO] \cdot [H_2]}{[H_2O]}$ *

C. $K_e = \frac{[CO] \cdot [H_2]}{[H_2O] \cdot [C]}$

D. $K_e = \frac{[H_2O]}{[CO] \cdot [H_2]}$

27. In the equilibrium system $N_{2(g)} + O_{2(g)} \leftrightarrow 2NO_{(g)}$($\Delta H = -180$ kJ) the process can shift to the forward reaction direction by:

A.Increasing of the pressure.

B. Decreasing of the temperature.

C. Increasing of the $O_2$concentration.*

D. Decreasing of the $N_2$ concentration.

28. The equilibrium of the system $CaCO_{3(g)} \leftrightarrow CaO + CO_2$ ($\Delta H>0$) is shifted to the right by:

A.Increasing of the pressure.

B. Catalyst adding.

C. Increasing of the temperature.*

D. Increasing of$CO_2$ concentration.

29. The equilibrium of the system $4HC1 + O_{2(g)} \leftrightarrow 2C1_{2(g)} + 2H_2O_{(g)}$ ($\Delta H<0$) is shifted to the left by:

A. Increasing$O_2$concentration.

B. Increasing $Cl_2$ concentration.*

C. Increasing of the pressure.

D. Catalyst adding.

30. The equilibrium of the system $4HC1 + O_{2(g)} \leftrightarrow 2C1_{2(g)} + 2H_2O_{(g)}$ ($\Delta H<0$) is shifted to the left by:

A. Increasing$O_2$ concentration.

B. Increasing of the temperature.*

C. Increasing of the pressure.

D. Catalyst adding.

31. The equilibrium of the system $C_{(c)} + O_{2(g)} \leftrightarrow CO_{2(g)}$ ($\Delta H<0$) is shifted to the right by:

A. Decreasing$CO_2$concentration.*

B. Increasing of the temperature.

C. Increasing of the pressure.

D. Increasing$CO_2$ concentration.

32. The equilibrium of the reaction $CO_2 + H_2 \leftrightarrow CO + H_2O$ directs to the left with the temperature increasing. What kind of this forward reaction?

A. Exothermic, $\Delta H>0$.

B. Exothermic, $\Delta H<0$.*

C. Endothermic, $\Delta H<0$.

D. Endothermic, $\Delta H>0$.

33. The equilibrium constant independents of:

A. The temperature.

B. The nature of reactant.

C. The nature of the solvent.

D. The concentration of reactant.*

34. How the catalysts influence on the chemical equilibrium displacement?

A. Potentiate the direct reaction.

B. Diminish the direct reaction.

C. Don’t influence.*

35. What factors action can displace the equilibrium of the process $H_2O + CO_2 \leftrightarrow H_2CO_3 + Q$ to the right?

A. Mixing.

B. Decreasing of the temperature.

C. Increasing of the pressure.

D. Increasing of $CO_2$ concentration.*

36. How the catalysts influence on the chemical equilibrium displacement?

A. Influence, but weakly.

B. Increase the final product recovery.

C. The catalysts displaces the equilibrium to the right and inhibitors to the left.

D. Don’t influence.*

37. For what of these reactions the hydrogen concentration increasing displaces the equilibrium to the left?

A. $N_2 + 3H_2 \leftrightarrow 2NH_3$

B. $2NH_3 \leftrightarrow N_2 + 3H_2$*

C. $2H_2 + O_2 \leftrightarrow 2H_2O$

D. $FeO + H_2 \leftrightarrow Fe + H_2O$

38. How does the decreasing of the temperature influence on the equilibrium state of the system $2SO_2 + O_2 \leftrightarrow 2SO_3 (\Delta H = –99\ kJ)$?

A. The equilibrium doesn’t displace.

B. The equilibrium displaces to the right.*

C. The equilibrium displaces to the left.

39. On the state of the chemical equilibrium of the reaction $2SO_2 + O_2 \leftrightarrow 2SO_3 (\Delta H < 0)$ is not affected by:

A. The change of the initial substances concentration.

B. Catalyst.*

C. The change of the temperature.

D. The change of the pressure.

40. For the equilibrium displacement to the product direction in the system $SO_{2(g)}+Cl_{2(g)} \leftrightarrow SO_2Cl_{2(g)}$ (☐H<0) you need:

A. Decrease the temperature. *

B. Decrease the $SO_2$ concentration.

C. Decrease the pressure.

D. Add the catalyst.

E. Increase the temperature.

## Tests for tutorial № 14

1. Redox reactions are called reaction in which disproportionation of _____ arise:

A. Hydrogen ions.

B. Hydroxide ions.

C. Electrons.*

2. The half-reaction of reduction is the process which proceeds with:

A. Hydrogen ions addition.

B. Release of electrons.

C. Hydroxide ions addition.

D. Absorption of electrons.*

E. Release of hydrogen ions.

3. The half-reaction of oxidation is the process which proceeds with:

A. Hydrogen ions addition.

B. Release of electrons.*

C. Hydroxide ions addition.

D. Absorption of electrons.

E. Release of hydrogen ions.

4. Galvanic elements are:

A. Devices for converting the heat energy into the work.

B. Devices for converting the chemical energy into the electric energy.*

C. Devices for converting the electric energy into the chemical energy.

D. Devices for determining the electrical conductivity of solutions.

5. Which value determines the direction of redox reactions?

A. Enthalpy change.

B. Entropy change.

C. Internal energy change.

D. Electromotive force.*

E. Standard electrode potential.

6. The conclusion of the possibility and direction of the oxidation-reduction processes can be draw from:

A. EMF of the reaction.*

B. Reactants concentrations.

C. The values of standard redox potentials.

D. Behavior of competing reactions with the participants of the redox process.

E. The nature of redox couple.

7. The conclusion of the completeness of the oxidation-reduction processes can be draw from:

A. Behavior of competing reactions with the participants of the redox process.

B. Reactants concentrations.

C. The values of standard redox potentials.

D. The equilibrium constant.*

E. The nature of redox couple.

8. The redox reaction is complete (99.9%) if:

A. $К_{equil.} \leq 10^{-8}$.

B. $К_{equil.} < 10^{8}$.

C. $К_{equil.} \geq 10^{8}$.*

D. $К_{equil.} = 1\text{-}10^{7}$.

E. $К_{equil.} = 10^{-8} - 10^{7}$.

9. The redox reaction proceeds directly if:

A. $К_{equil.} < 1$.

B. EMF < 0.

C. $К_{equil.} \leq 10^{-8}$.

D. EMF > 0.*

10. For which redox couple the value of the redox potential depends on the pH:

A. $Sn^{4+}/Sn^{2+}$.

B. $MnO_4^-$, $8H^+/Mn^{2+}$.*

C. $I_2/2I^-$.

D. $Fe^{3+}/Fe^{2+}$.

11. For which redox couple the value of the redox potential doesn't depend on the pH:

A. $BrO_3^-$, $6H^+/Br^-$.

B. $Fe^{3+}/Fe^{2+}$.*

C. $BrO_3^-$, $6H^+/Br^-$.

D. $MnO_4^-/MnO_2\downarrow$, $4OH^-$.

12. For potentiometric measurement use:

A. Polarimeters.
B. Coulometers.
C. Polarographes.
D. Potentiometers.*
E. Refractometers.

13. Point out the method of instrumental analysis, based on the measurement of electric potential difference between the indicator and the standard electrodes dipped into the solution with the analyte:

A. Potentiometry.*
B. Coulometry.
C. Conductometry.
D. Voltammetry.
E. Polarography.

14. In the potentiometric analysis method use the electrodes, which distinguished by the nature of the reversibility on the electrodes of the first and second kind. Point out the electrode of the first kind:

A. Mercury.*
B. Ion-selective.
C. Silver-chloride.
D. Glass.
E. Calomel.

15. In the potentiometric analysis method use the electrodes, which distinguished by the nature of the reversibility on the electrodes of the first and second kind. Point out the electrode of the second kind:

A. Calomel.*
B. Silver.

C. Mercury.

D. Copper.

E. Platinum.

16. The value of the equilibrium potential is calculated by the equation:

A. Ilkovich.

B. Nikol'skii.

C. Raleigh.

D. Nernst.*

E. Boltzmann.

17. Quinhydrone electrode is:

A. Electron carrier.

B. Sensitive to hydrogen ions concentration.*

C. Sensitive to cations concentration.

D. Sensitive to anions concentration.

18. Platinum electrode is:

A. Electron carrier.*

B. Sensitive to hydrogen ions concentration.

C. Sensitive to cations concentration.

D. Sensitive to anions concentration.

19. Glass electrode is:

A. Electron carrier.

B. Sensitive to hydrogen ions concentration.*

C. Sensitive to cations concentration.

D. Sensitive to anions concentration.

20. Antimony electrode is:

A. Electron carrier.
B. Sensitive to anions concentration.
C. Sensitive to cations concentration.
D. Sensitive to hydrogen ions concentration.*

21. Point out the indicator electrode for potentiometric redox titration:
A. Glass.
B. Mercury.
C. Platinum.*
D. Hydrogen.
E. Quinhydrone.

22. Point out the essential feature required of the indicative electrochemical reactions:
A. Replacement of one indicator reaction proceeds before the equivalence point, to the other reaction, which proceeds after the equivalence point.*
B. Sufficient reaction rate.
C. Stoichiometry.
D. Irreversibility.
E. The possibility of fixing the end point of titration.

23. During the determining the pH of the solution as the indicator electrode is used:
A. Calomel.
B. Glass.*
C. Silver.
D. Platinum.
E. Silver-chloride.

24. During the determining the pH of the solution as the indicator electrode is used:
A. Copper.

B. Platinum.
C. Mercury.
D. Silver-chloride.
E. Quinhydrone.*

25. During the determining the pH of the solution as the indicator electrode is used:

A. Silver-chloride.
B. Platinum.
C. Mercury.
D. Antimony.*
E. Copper.

26. Point out which electrodes are used for composition of the galvanic cell for potentiometric titration with acid-base interaction reactions:

A. Platinum and calomel.
B. Calomel and silver-chloride.
C. Hydrogen and antimony.
D. Glass and silver-chloride.*
E. Hydrogen and quinhydrone.

27. Point out which electrodes are used for composition of the galvanic cell for potentiometric titration with redox interaction reactions:

A. Platinum and silver-chloride.*
B. Calomel and silver-chloride.
C. Silver and platinum.
D. Glass and silver-chloride.
E. Platinum and quinhydrone.

28. What is the name of biopotential, which occurs at the boundary between the two solutions separated by a semipermeable membrane?

A. Diffusion.
B. Membrane.*
C. Electrode.
D. Demarcation potential.

29. The electrodes of the first kind are reversible by:
A. Cation, common with the electrode material.*
B. Anion.
C. For various ions sorbed solid or liquid membrane.

30. The electrodes of the second kind are reversible by:
A. Cation, common with the electrode material.
B. Anion.*
C. For various ions sorbed solid or liquid membrane.

31. Ion-specific electrodes are reversible by:
A. Cation, common with the electrode material.
B. Anion.
C. For various ions sorbed solid or liquid membrane.*

32. What is the essence of the potentiometric analysis?
A. In the measurement of the optical density of the sample solution.
B. In the measurement of the EMF of the sample solution.*
C. In the change of electrical conductivity of the sample solution.
D. In the measurement of the light transmission of the sample solution.

33. Choose the mathematical expression of the Nernst equation:
A. $\mathrm{EMF} = E^0_{\mathrm{Ox}} - E^0_{\mathrm{Red}}$
B. $K_{\mathrm{equil.}} = 10^{\frac{(E^0_{\mathrm{Ox}} - E^0_{\mathrm{Red}})\cdot n_1 \cdot n_2}{0{,}059}}$

C. $\mathrm{EMF} = \mathrm{E}_{\mathrm{p\,Ox}} - \mathrm{E}_{\mathrm{p\,Red}}$

D. $\mathrm{E}_{\mathrm{p\,Ox/Red}} = \mathrm{E}^{0}_{\mathrm{Ox/Red}} + \frac{0{,}059}{\mathrm{n}} \cdot \lg \frac{[\mathrm{Ox}]}{[\mathrm{Red}]}$ *

34. In what equation calculated the value of the resting potential:

A. $\mathrm{E}_{\mathrm{membr.}} = 0{,}059\lg \frac{[\mathrm{Na}^{+}_{\mathrm{intern.}}]}{[\mathrm{Na}^{+}_{\mathrm{extern.}}]}$

B. $\mathrm{E}_{\mathrm{membr.}} = 0{,}059\lg \frac{[\mathrm{K}^{+}_{\mathrm{intern.}}]}{[\mathrm{K}^{+}_{\mathrm{extern.}}]}$ *

C. $\mathrm{E}_{\mathrm{membr.}} = 0{,}059\lg \frac{[\mathrm{K}^{+}_{\mathrm{extern.}}]}{[\mathrm{K}^{+}_{\mathrm{intern.}}]}$

D. $\mathrm{E}_{\mathrm{membr.}} = 0{,}059\lg \frac{[\mathrm{Na}^{+}_{\mathrm{extern.}}]}{[\mathrm{Na}^{+}_{\mathrm{intern.}}]}$

35. In what equation calculated the value of the action potential:

A. $\mathrm{E}_{\mathrm{membr.}} = 0{,}059\lg \frac{[\mathrm{Na}^{+}_{\mathrm{extern.}}]}{[\mathrm{Na}^{+}_{\mathrm{intern.}}]}$

B. $\mathrm{E}_{\mathrm{membr.}} = 0{,}059\lg \frac{[\mathrm{K}^{+}_{\mathrm{intern.}}]}{[\mathrm{K}^{+}_{\mathrm{extern.}}]}$

C. $\mathrm{E}_{\mathrm{membr.}} = 0{,}059\lg \frac{[\mathrm{K}^{+}_{\mathrm{extern.}}]}{[\mathrm{K}^{+}_{\mathrm{intern.}}]}$

D. $\mathrm{E}_{\mathrm{membr.}} = 0{,}059\lg \frac{[\mathrm{Na}^{+}_{\mathrm{intern.}}]}{[\mathrm{Na}^{+}_{\mathrm{extern.}}]}$ *

# CONTENT

**Thermodynamic and kinetic regularity of the reaction behavior and**